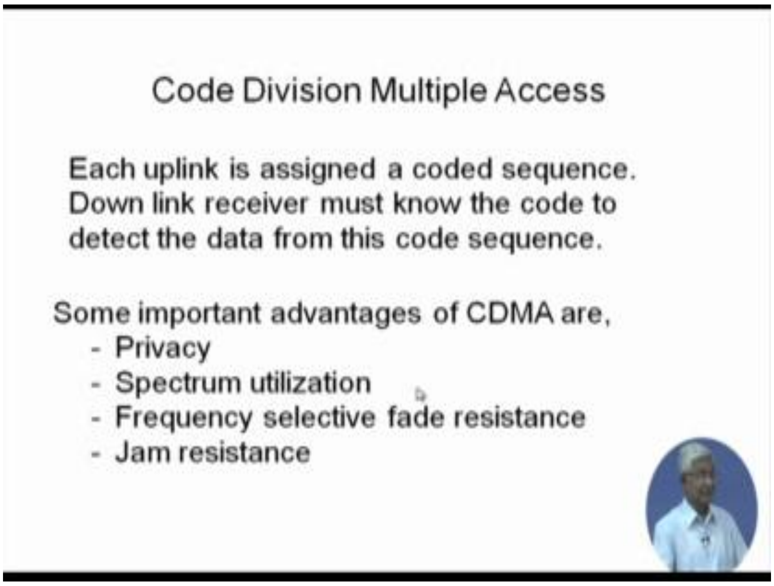
**Satellite Communication Systems**
**Prof. Kalyan Kumar Bandyopadhyay**
**Department of Electronics and Electrical Communication Engineering**
**Indian Institute of Technology, Kharagpur**

**Lecture - 30**
**Multiple Access-5**

Welcome back. We were discussing about the Multiple Access using the satellite. Now in that already we have covered very common multiple access which is frequency division multiple access or in short FDMA and some parts or some issues on time division multiple access that is TDMA.

(Refer Slide Time: 00:49)



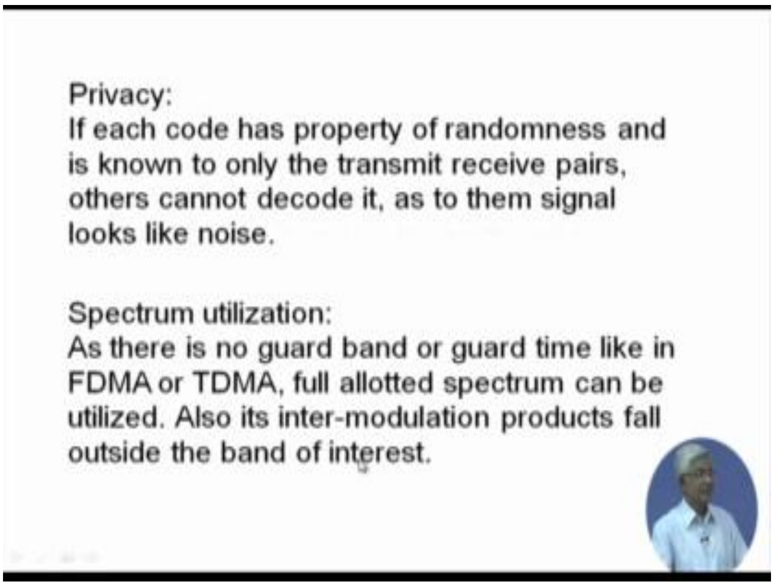

Now, we take up another popular multiple access scheme which called code division multiple access; CDMA. Now code division multiple access is in that case you are using the different code for each station. Each up link station is assigned a coded sequence. A coded sequence is used for each bit that is the bit can be 1 or 0. So, for that the coded sequence that 1 or 0 will be modulated with that coded sequence. That means it is very simple term we can do it this way; if it 1 then the coded sequence will go, if it is 0 the inverse of the coded sequence will go; that that is.

.

Now, the down link of the receiver must know the code what transmission has been banned which code was transmitted. That is the meaning of that particular code for 1 and 0. So, it can detect the data from this code sequence. The advantage of this is that the transmitter and receiver pair only knows the code all other codes will look like a noise to all others this code is look like a noise. So, it gives certain advantages one is the privacy and there is a spectrum is fully utilized not like FDMA and some guard bands are left etcetera. So, spectrum is fully utilized.

And there the other two advantages we get that if there is a frequency selective fade which normally does not happen in this geosynchronous satellite situation, but sometimes depending on the atmospheric condition or some multi path is happening they it may happen. In case of mobile satellite communication there is MSS it may happen. The most interesting part of the CDMA where the defense people they feel that they should use that is it is jam resistant. Let us just quickly go through each of them.

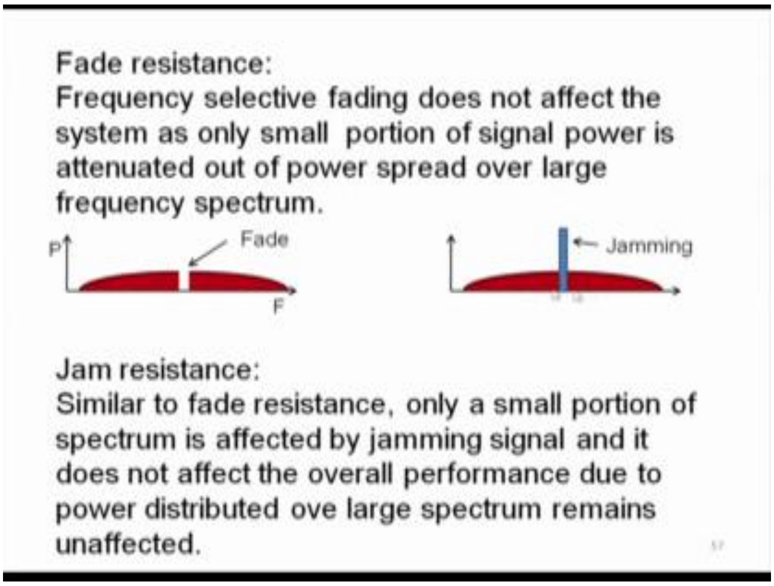
(Refer Slide Time: 03:03)




This privacy that is if each code has property of randomness within the code period and that is known only the transmit receive pairs, then others cannot decode it, as to them a this signal look like noise. Same thing is true for this transmit receive pair from another transmit receive pair. So, it is quite private, but it should have a randomness property and it should be known to this pair.

Spectrum utilization there is no guard band like to TDMA or like FDMA frequency band is not separately allotted between the burst there is no burst it is one single continuous and there is no burst there why there is no guard time like TDMA. So, it is a continuous use of the full transponder the bandwidth and power by all the station simultaneously. That means, full allotted spectrum can be utilized. Also another things since all the carriers are coming simultaneously there will be lot of inter modulation product that will fall outside the band of interest.

(Refer Slide Time: 04:18)




Fade resistance is the frequency selective fading does not affect the system as it is spread quite large, so only one small portion of the single power is attenuated due to frequency selective fade out of the spread power over the large frequency spectrum.

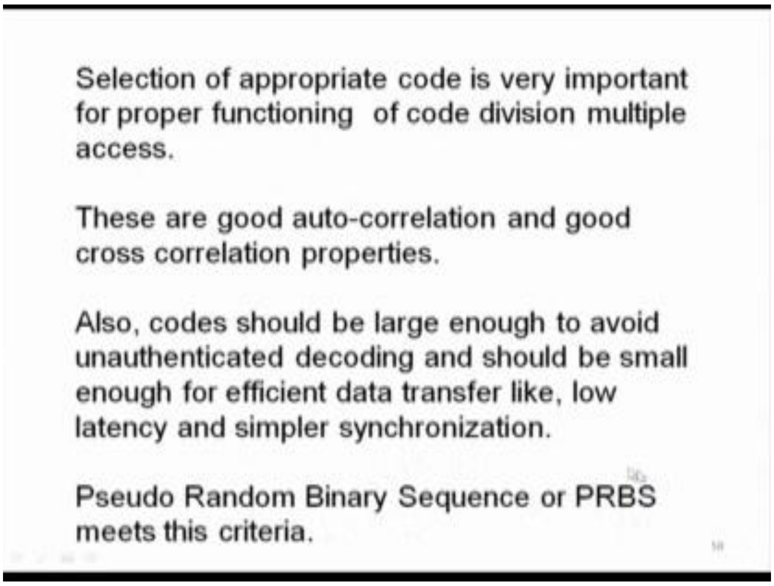
Pictorial let us see this is power this is the frequency and this red shaded area is the spread and in that one small portion of the frequency is faded, so no power at that place.

Even if we receive like that since most of the power is present and only one small fraction is lost you can still recover it, so it is fade resistance.

The opposite to that is jam resistance. Similar to fade resistance only a small portion of spectrum is affected by jamming, putting with a high amount of another power so that this part looks like a noise. And it does not affect the overall performance due to power distributed over large spectrum remains this picture we just reverse it; instead of fade there is a jamming here.

So, only this portion of the frequency spectrum is affected due to jamming this all things are. So therefore, by the ratio we can find out that it jam resistance.

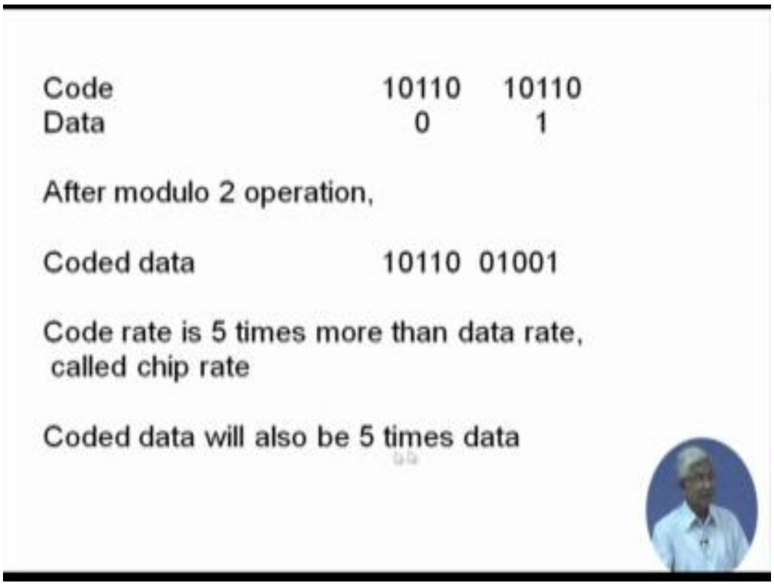
(Refer Slide Time: 05:43)




The selection of the appropriate code is very important for proper functioning that code division multiple access. So, it should have a good auto-correlation property and good cross correlation property. When the other code is falling over it you your detection should not get disturbed. Similarly, when you are trying to receive your own code you should be able to detect it properly so side looks of that. You are familiar with auto-correlation, cross correlation.

So, also other another issue is that when it is communicating that the code should be large enough to avoid unauthorized or unauthenticated decoding that is a privacy part. But then the code should be small enough so that the efficient data transfer like low latency and simpler synchronization is possible. So, there is certain contradicting requirement you try to spread it more for privacy you have to make it small otherwise your synchronization time will take a more time, even the code changes.

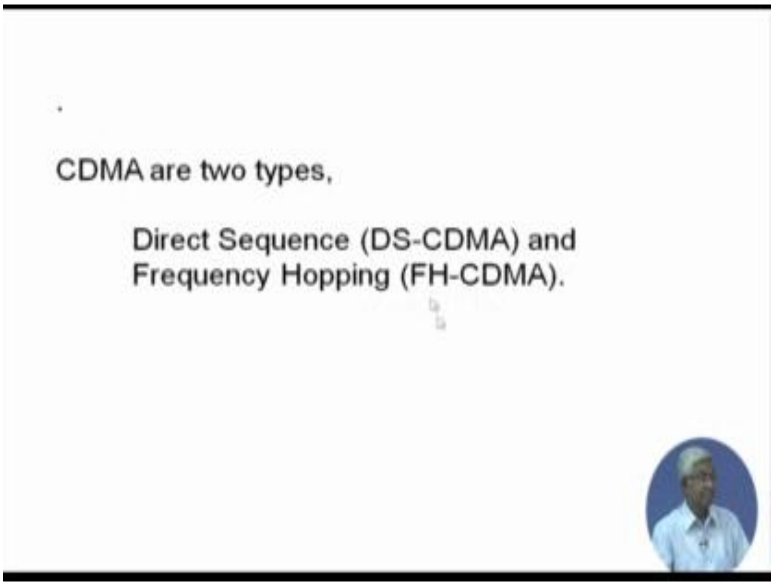
(Refer Slide Time: 06:57)




Now, the PRBS pseudo random binary sequences meet this criteria many times. I hope you are familiar with the PRBS we will just briefly tell you about that let us the code let say data is 0 and 1 and for 0 I have made a code 10110 and here a code is 10110 so in this inversed. After module two operations this one I am maintaining same, in case of 0 in this case let us taken 0 will maintain the same 1 will be inverting, so 1 is inverting in this code. 1 is made 00 is made one double made double 00 is made 1. This is the coded data that will be transmitted.

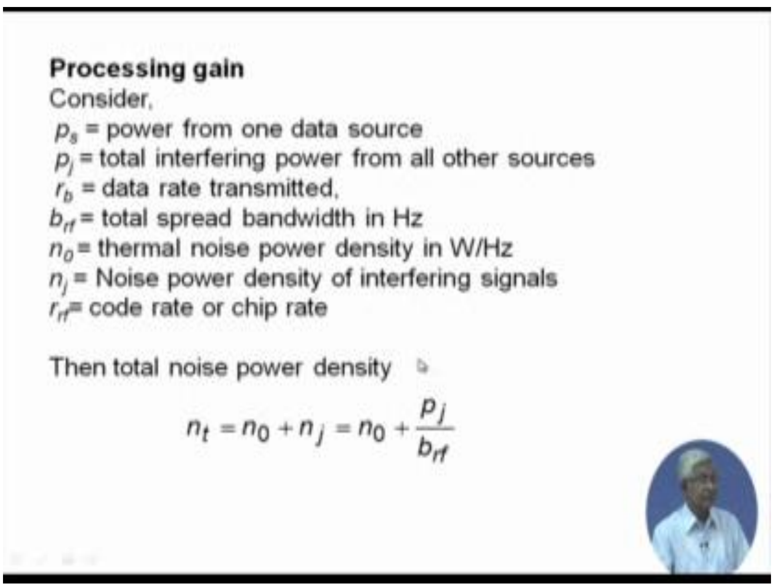
So, instead of 0 and 1 the coded data is transmission, but you see there are only two bites here there are 10 bites that means 5 times we have increase the data rate. So, code rate is 5 times more than data rate. We can call it code rate or people use another term which is called chip rate, means code rate or chip rate is 5 times more than the data. And data itself is 2 bits here it is 10 bits so coded data is 5 times the data; both are then means the same thing.

(Refer Slide Time: 08:12)




The CDMA are of two types; one is called direct sequence still CDMA another is called frequency hopping CDMA

(Refer Slide Time: 08:25)



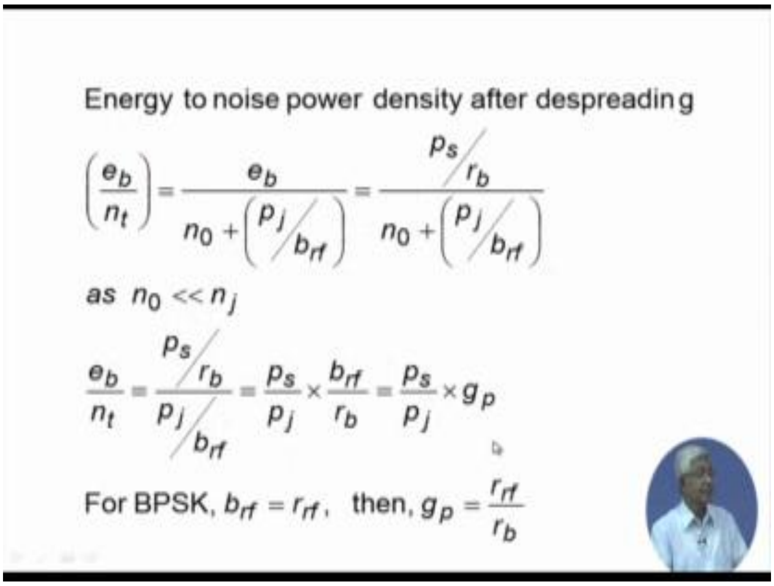
Let us look at now go into to the detail of direct sequence and frequency hopping CDMA. In case frequency hopping based on the code sequence you correspondingly map it into different frequency. At different frequencies power will go and it will switch as if at the code rate or chip rate it is switching so that is frequency hopping. And in case of direct sequence and this sequence as it is going as a explaining.

Now let us look at some of the quick properties of the CDMA is called Processing Gain. Let us try to calculate and try to show how and how this gain comes. There are lot of small term terms you should know the normal feature small P s is power from 1 data source P j is total interfering power. In case of CDMA in 1 station communicating and all other stations communications over the same bandwidth is coming, so they are activating as jam

So, you can call it total interfering power or P j as a total P jam that is the total power. So, P j is much more than P s, one station is transferring with P s P j is all other stations transmitting total power. R b data rate that is transmitted let us assume all stations are transmitting at the same data rate. And that data rate is spread over a bandwidth that is b rf that is spread bandwidth you have seen the picture of that, n 0 is the thermal noise power density in watts per hertz is for frustration. And n j is that noise power density of the interfering signal. That is the signal power density a signal power and this noise power density. And r f is the code rate of the chip rate that r b is the data rate and the r rf is a chip rate.

Now, total noise power density if you called nt that is thermal noise of the source at the receiver. Thermal noise of the source and the chiming noise; chiming noise in this case it is interfering noise that is nj. And what is nj? Nj is P j by b rf over the bandwidth and that is noise power density over the bandwidth. So, total jamming power divided by the bandwidth, jamming power or interfering power. So, n t is equal to n 0 plus P j by b rf try to remember.

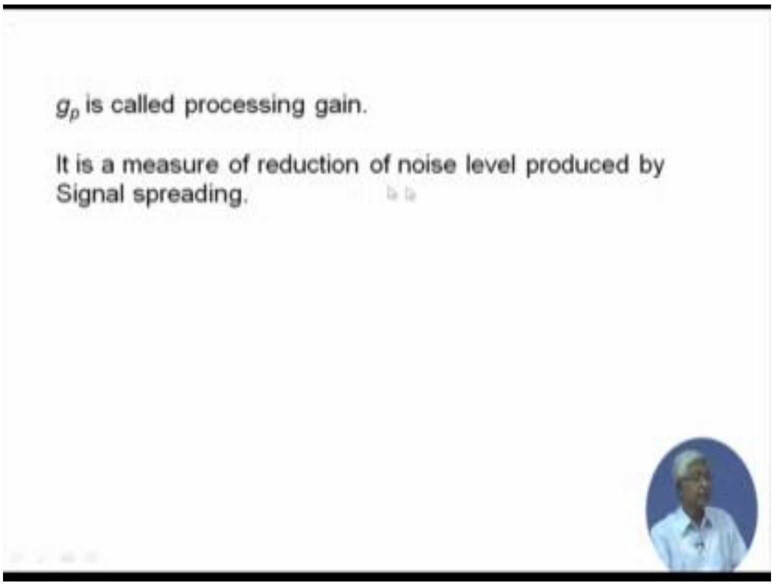
(Refer Slide Time: 11:01)




Now energy to noise power density after dispreading is e b by n t total noise power. So, n t is equal to n 0 is P j by b rf we have seen in last page. So, e b by n 0 plus P j by b rf. Now, e b energy per bit is that power station is divided by r b. Earlier we used to call c by n that is a c that is that is c is equal to e b into r b here we are calling it P s power per individual sources of. P s by r b e b is equal to P s by r b and denominator remains same.

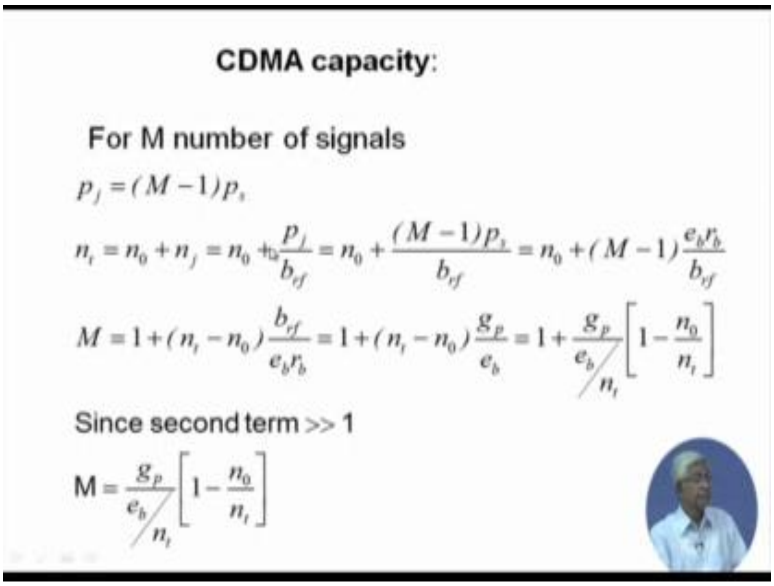
Now, since the jamming power size is much more, n t is much more compare to in our n j no n t is equal to n 0 plus n j. N j is much more than n 0 because that is all interfering power n 0 is one thermal power from one source. So, you can neglect the first term on the denominator. So, then it becomes e b by n t is P s by r b divided by P j by b r f. So, in terms of power you can put P s by P j into b rf by r b. This b rf by r b is called the gain, b rf is the total spread r b is the individual bit rate individual bit rate is multiplied by the code rate that is how you got the spread. In case of BPSK the b rf is equals to r rf. So, coding gain or processing gain whatever you call of CDMA gain g you can call it small g p; gp is r r f by r b or b rf f by r b which (Refer Time: 12:54). Now let us try to calculate what should be the capacity like we calculated the FDMA capacity TDMA capacity. What is the capacity in CDMA?

(Refer Slide Time: 13:02)




Now let us briefly I told you g p is called processing gain as a measure of reduction of the noise level produced by the signal spreading in it is.

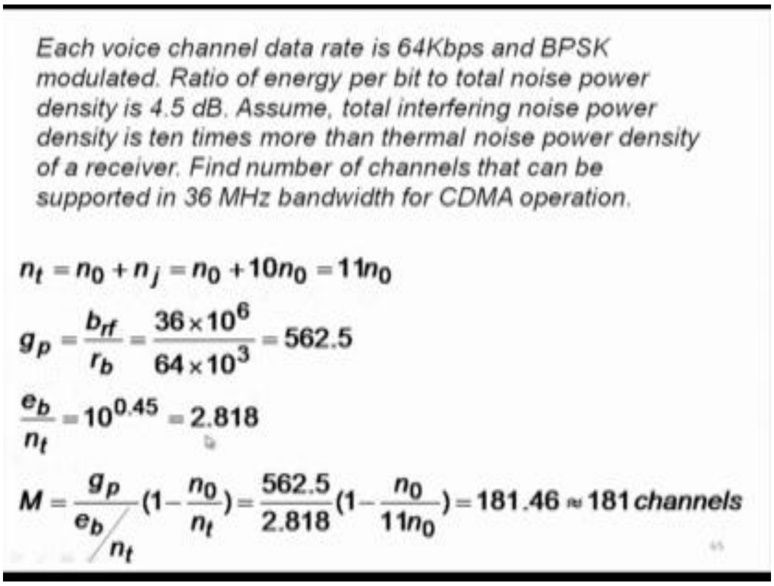
(Refer Slide Time: 13:13)




Now, capacity calculation let us P j is interfering power which is let us say M number of the stations are there n signals are there, so the main signal minus 1 all other are interfering so it is M minus 1 into everybody is transmitting a P s; so into P s. And as we started their earlier n t is a total noise power density is n 0 plus n j interfering power plus thermal noise. And n j is P j by b rf and P j is M minus 1 into p so n 0 plus M minus 1 P s by b rf that is equal to now P s we can replace with e b into r b. So, M minus 1 into e b r b by b rf. Now by rearranging the terms M is equal to 1 plus n t minus n 0, because this was n t here so n t minus n 0 into b rf by e b r b and that one is changed. So, M is equal to plus n t minus 1 0 b rf by e b r b. And then b rf by r b is passing gain or the coding gain whatever we called CDMA gain which is g p, so it become 1 plus n t minus n 0 g p by e b. Now if I take it out in terms e b by n t, so n t is taken out from inside so it becomes 1 plus g p by e b by n t 1 minus n t by n 0 by n t.

Now since these second term is much larger than one you can depending on the size you can neglect the term. So, M is g p by e b by n t 1 minus n 0 by n t. That is the total number singles that can be transmitted assuming all of them are transmitting at P s bitrates are same all other assumptions are valid. So, M is equal to g p by e b by n t 1 minus n 0 by n t.

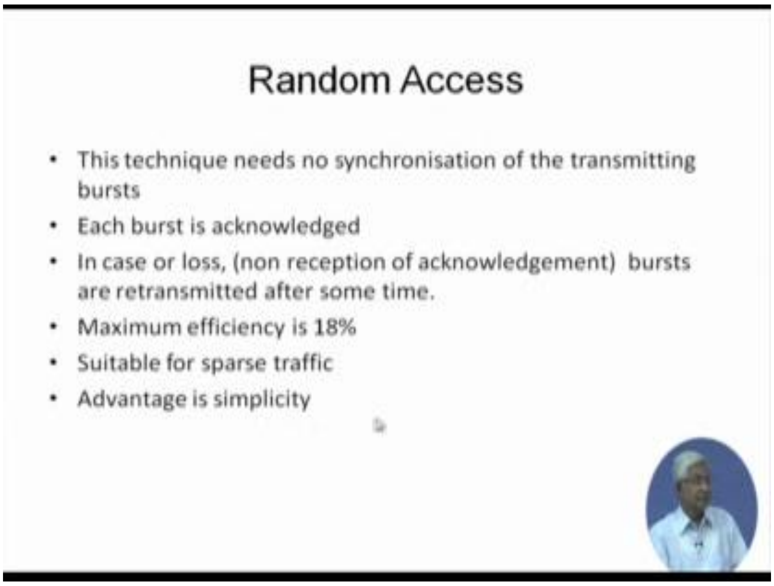
(Refer Slide Time: 15:16)




Let us try to quickly calculate; for 64 kilo bit and BPSK modulated signal, where e b by n t is 4.5 dB assuming total interfering noise power is 10 time more than the thermal noise power n t is equal to 10 times than n 0. Then find the number of channels that can be supported in 36 mega hertz b rf is given here.

So, calculation is very simple n t is n 0 plus n j which is n j is 10 time the n 0. So, it is 11 n 0, g p is b rf given r b given get it 562.5, e b by n t comes out to be 2.818 that dB is put in to ratio. So M is g p by e by n t 1 minus n 0 by n t you put the numbers you will get 181.46. So, it is about roughly 181 channels, so this is how estimation can done.

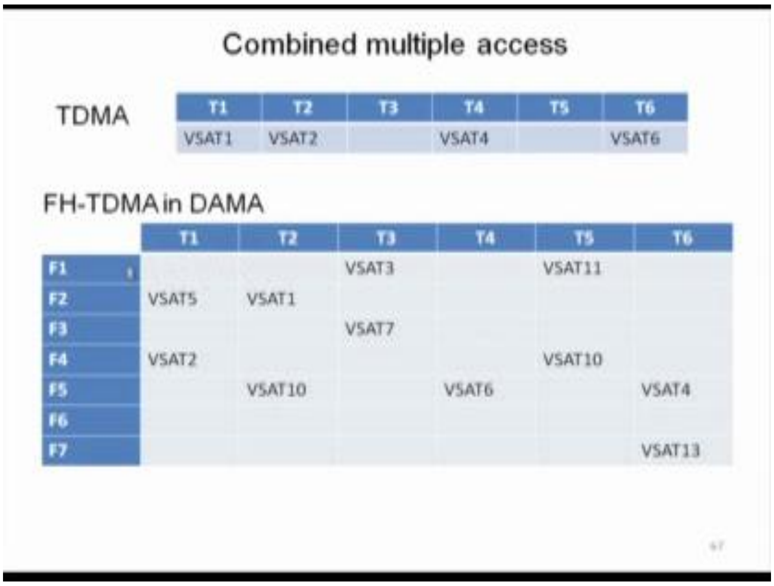
(Refer Slide Time: 16:16)




Now, that briefly we have discussed about three major multiple access system which are FDMA, TDMA and CDMA. One access which is also used in satellite communication in some cases is called random access. This technique needs no synchronization of the transmitting bursts. So, though it is transmitted in terms if time it is not frequency sharing it is time sharing, but the sharing you do not need any synchronization. So, there is a possibility of loss because since there is no synchronization two transmissions may simultaneously go and the receiver will not be able to detect it out.

So, each bursts is acknowledged whether it is been received correctly is acknowledged. And if it is not acknowledge in case of loss non-reception of the acknowledgement bursts re transmitted after some time. So, it is assuming that I have a slow communication rate and there is non-continuous busty traffic, then this is the very simple scheme because you do not know its synchronization you do not need full TDM. But the loss is more so the efficiency is because there will lot of clashes as the number of stations are increasing and a number of traffic is increasing. So, maximum efficiency theoretically is calculated as 18 percent people operate at 10 percent. Is suitable for sparse traffic because it is having a simple nature is suitable for sparse traffic. Advantages is simplicity

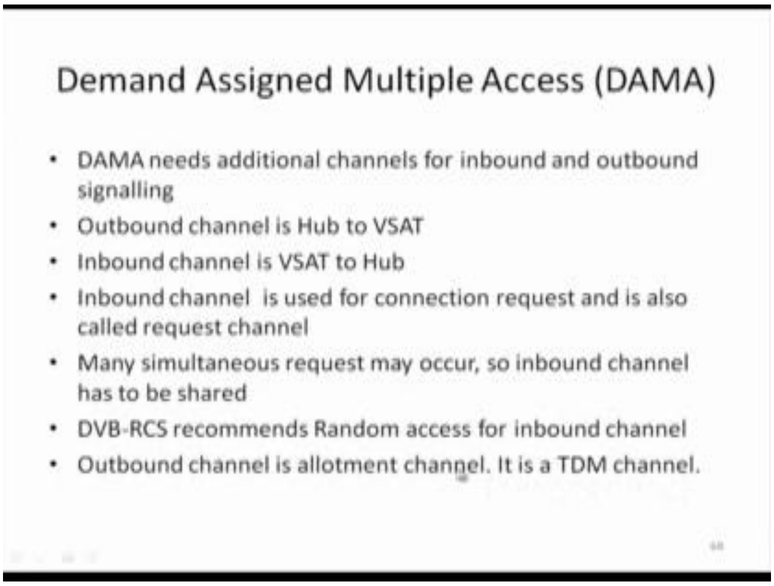
(Refer Slide Time: 17:49)




Now, let us go quickly into combination of multiple access; we extracted lot of advantages in that let us say TDMA. TDMA if it is a non continuous traffic say I am just showing a frame where the times loss T 1 to T 6 are shown here. And some VSATs are allotted they are transferring. So, these are three at that movement at this particular movement when the snapshot is taken then there is no data, so times for T 3 is not being used. Similarly VSAT 5 has no data its not be used, it is lot of under utilization there. Now that can be avoided by putting this into frequency and time domain simultaneously, since is called FH-TDMA. It normally operates in demand assign multiple access mode, DAMA mode.

The frequency slot the frequency is bands are given and for each frequencies band times slots are taken. Each frequency band 6 times slots are taken. There are 7 frequency bands here small spectrum mat. It is assume that VSAT data is very small so after modulation you take very small amount of bandwidth and time is spread. So, depending on which slot is available in terms this matrices a time frequency matrices which slot is available the center station a lot. So, it is demand and particular VSAT wants to come in so it demands and depending on the availability of the slot. So, it put randomly. This is very what we used in dB r c s to.

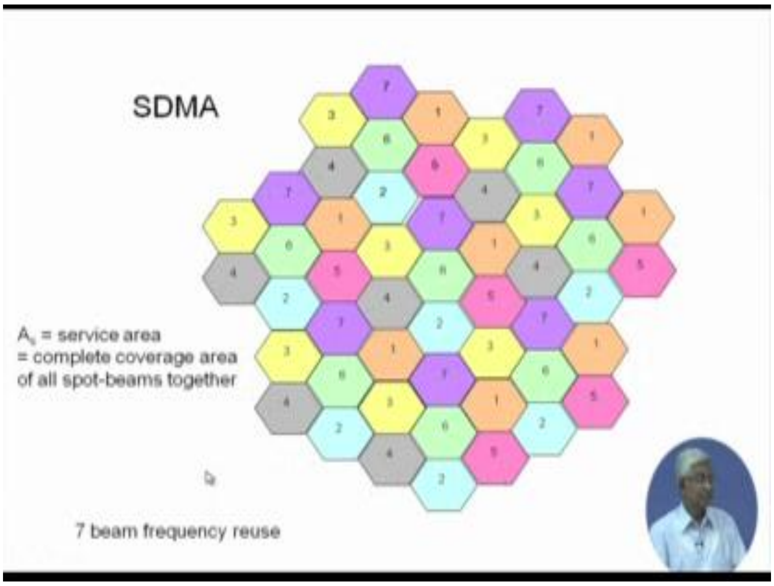
(Refer Slide Time: 19:29)




This DAMA needs additional channel that is very important that you have to give a request and you have to give a allotment is called in bounds to the Hub is remote station of reset is going to the Hub that is called inbound looked at from the Hub point of view. And Hub is giving the allotment which goes outbound, so inbound is being shared outbound channel is Hub to VSAT, whereas inbound channel is VSAT to Hub. Now there are many resets are might be requesting inbound channel has to be shared it is used for connection request there is also called request channel. And many simultaneously request may occur so inbound channel has to be shared. And DVB-RCS that is digital video broad casting return channel wire come satellite this is standard which is be used by present day VSAT technology. There are some of which are proprietary and this is standard by European standards which is been followed most of the cases. That recommends that this inbound channel for random access multiple access, because this is the spars traffic. Only sometimes some VSATs come not the all VSATs simultaneously ask for the allotment.

So, it is that is why use and random access. They have other access also one of the random accesses for this inbound channel. And outbound channel is in TDM because it is allotted by the Hub and meant for everybody to look into it, so it is a TDM channel. So, this is the DAMA arrangement.

(Refer Slide Time: 21:05)



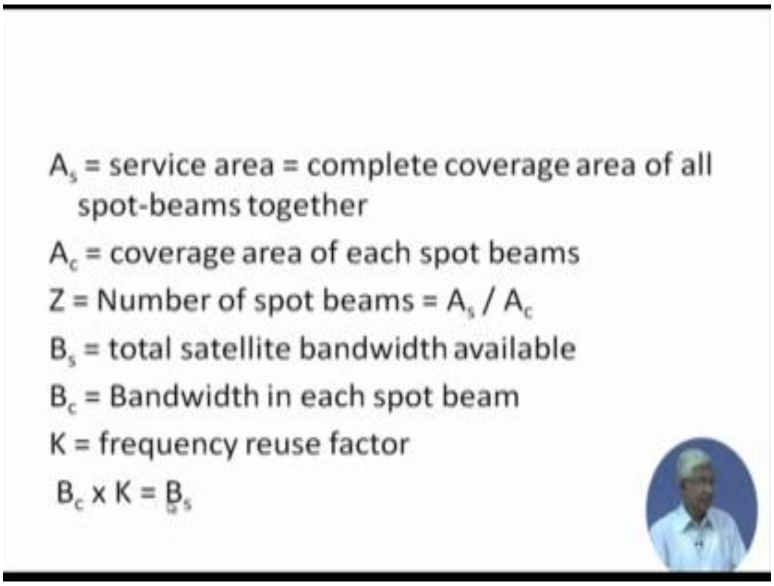

Now let us go into another multiple access which is space division multiple access; SDMA. Let us say there is multiple beam satellite, a satellite which has multiple beams. Just like our cellular network this concept is simple cellular network I have shown it is a 7 beam concept like a 7 cell concept etcetera cells. In beams a it will be just like cellular it will be circular or elliptical here first simplicity we merit channel for easy understanding.

So, let say A is the total service area which is larger than this and there is complete coverage area for all spot beams together and this is the 7 frequency reuse 7 beam each beam has one particular frequency let us assume for simplicity. And service area is much larger and this cluster of 7 beams can be repeated, like this so that one of the beam which is using say this the center of the here which is using frequency 6 f 6. The second use of the f 6 is quite for away. So, if it is beam it is side low and even null will fall very small amount of energy will fall here corresponding from to here to here.

So, the co channel interference is very less we put it far away. Say this one say this is frequency one have been number one and in this cluster being number one is far away; 2 beams, two and half beams away it is. So, it beams patterns radiation patterns of the designs such that the very small energy from this beam will fall into this beam often to this beam to this beam so that co channel inference is less, so this is how.

This type of a cluster of 7 beams can be used to complete the coverage area. So, let us say this is the satellite coverage area approximately and have used many sets 7 beam clusters so I can use the frequency of many times.

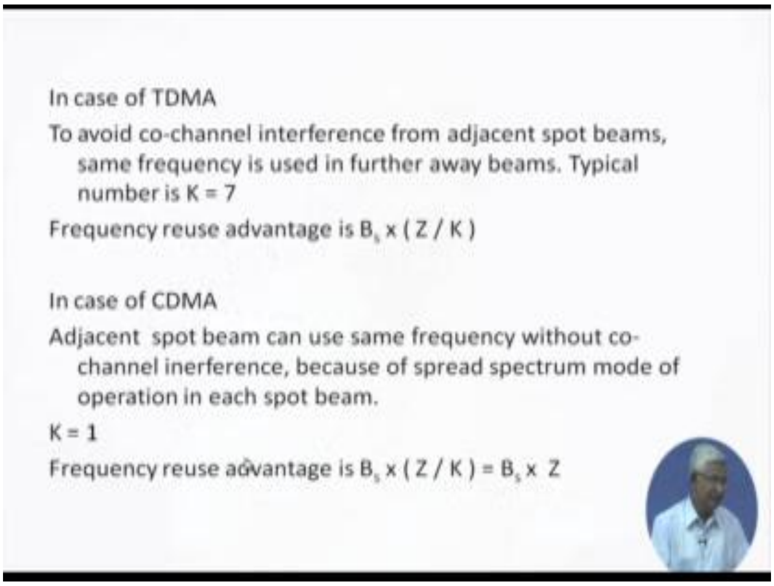
(Refer Slide Time: 23:20)




Let us say A s is the service area that is complete coverage area of all spot beams together as you mentioned earlier. A c is the coverage area of the each spot beams, Z is the number of spot that is obviously the division of these two. And the total satellite band width available is B s.

Now, how that can be used is, B c is the bandwidth in each spot beam, and K is the frequency reuse factor. In this case seven in the earlier slide what we are shown. So, the K times B c will be our B s or the other way the satellite total band width is can be given that K times B c. So, as the K goes up is you can see reuse is less.

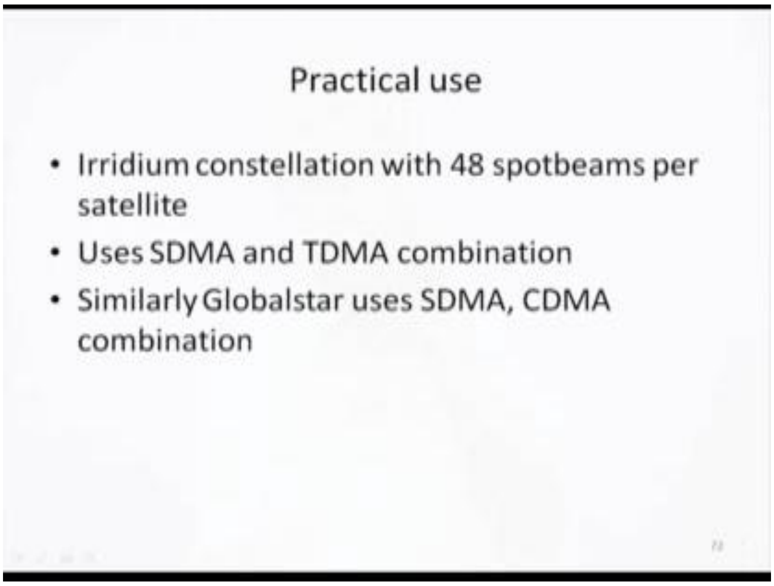
(Refer Slide Time: 24:23)




In case of TDMA to avoid co channel inferences from adjacent spot beams same frequency is used in a far away beam is using the same. In this case we have shown K is equal to 7 could be it could be flatter than depending on that type of the antenna gain just now we have said antenna radiation pattern what is selected in the each beam. So, frequency is advantage you get B s is used Z by K times Z by K times the frequency can be reused. That is the virtual bandwidth is increased Z by K time of D s if it was a one single spot one single beam then only done with B s could have been used. Now since we have use the efficiency Z by K times the B s is used very good advantage.

But you just look at it from instead of TDMA if you have put CDMA. In case of CDMA what happens? Adjacent spot beam use of same frequency because it is code based so that act as a noise so co channel is interference is not there. So, without co channel interference we can use the same frequency in the adjacent beam because of the spread spectrum mode of operation in each spot beam. So, here then K is equal to 1; that means, you see that frequency reuse advantage is B s into Z by K k is equal to 1 B s is equal to Z which is larger than this; so CDMA, SDMA if you use the combination which is better.

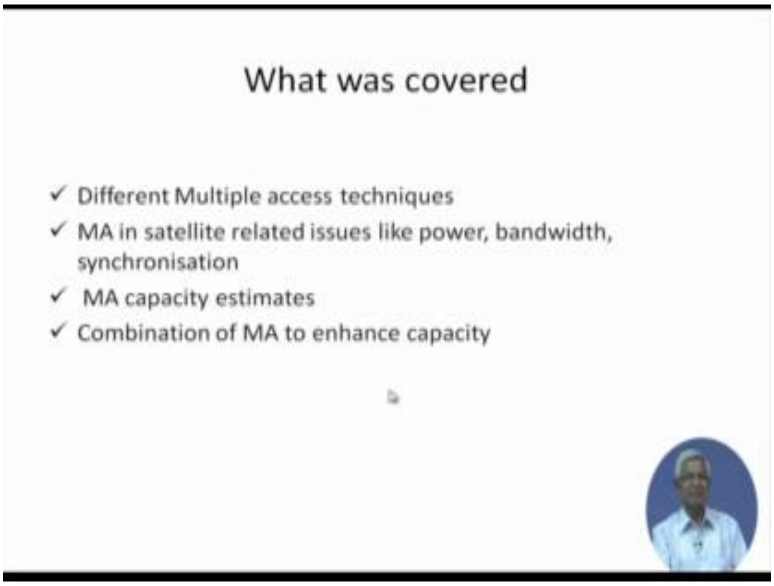
(Refer Slide Time: 26:05)




And practically this people use that way like there is a irridium satellite constellation with each satellite has 48 spot beams and there is a 66 satellites that cover the whole globe where is the commercial availability it is used by some as specialized organization. They use the SDMA and TDMA combination, whereas there is a complimentary another satellite is available at another cluster of satellite is global star of the company they used SDMA CDMA combination.

So, there are practical uses of this. So, like this you can enhance the capacity of the satellite multiple access capacity of the satellite.

(Refer Slide Time: 26:51)




So, what we are covered till now in the total multiple access a couple of lessons what we had; that is different types of multiple access techniques briefly and major multiple access technique. And then the satellite related issues like bandwidth power and synchronization. And then the capacity for each of this multiple access very brief quick calculation type of thing, and of course enhancement by combining multiple access to enhance this capacity. With this we complete the course on multiple accesses. Thank you very much will continue with our new topic in the next session.

Thank you.